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Evaluation of Dentin Root Canal Permeability After Instrumentation and Er:YAG Laser Application

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Background and Objectives: **Smear layer removal with EDTA from root canal walls allows greater cleaning and disinfection of root canals. However, because Er:YAG laser acts on the removal of the smear layer, the objective of investigation was to analyze in vitro the effect of Er:YAG laser on dentin root canal wall permeability after endodontic instrumentation and irrigation with water or sodium hypochlorite and Er:YAG laser application.**
Study Design/Materials and Methods: **A total of 25 extracted human maxillary incisors were divided into five groups: Group I, instrumentation with deionized distilled water as the irrigating solution; Group II, instrumentation with 1% sodium hypochlorite as the irrigating solution; Group III, instrumentation with deionized distilled water as the irrigating solution and Er:YAG laser application; Group IV, instrumentation with 1% sodium hypochlorite solution as the irrigating solution and Er:YAG laser application; Group V, instrumentation only up to #20 file with deionized distilled water as the irrigating solution and Er:YAG laser irradiation. The laser parameters were 15 Hz, 140 mJ, total energy 42 J, 300 pulses (Kavo Key Laser). Copper sulfate (10%) was used to evaluate dentin permeability. The penetration of copper ions into the dentinal tubules was observed using 1% rubeanic acid, which reveals copper ions, forming a stained compound ranging in color from deep blue to black. Transverse sections (500-μm thick) were obtained with a diamond disk from the cervical, middle, and apical thirds.**
Results: **The instrumentation of the root canal that used water as the irrigating solution followed by Er:YAG laser irradiation promoted the greatest increase in dentin permeability. The use of Er:YAG laser, 1% sodium hypochlorite + Er:YAG, and 1% sodium hypochlorite used alone showed an intermediate capacity of increasing dentin permeability. The use of water as the irrigating solution without Er:YAG laser promoted the least dentin permeability.**
Conclusions: **The use of water as the irrigating solution after instrumentation and Er:YAG laser irradiation was an effective procedure for increasing dentin permeability. Lasers Surg. Med. 26:277–281, 2000.**

Key words: irrigation; root canal; dentin permeability; Er:YAG laser

INTRODUCTION

McComb and Smith [1] were the first to report the existence of smear layer in root canals after instrumentation. The smear layer originates

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from instrumentation, and is composed of dentin chips with organic and inorganic particles. Many studies such as those of Aktener and Bilkay [2] and Matsuoka et al. [3] have shown that chemical-mechanical preparation associated with irrigating solutions does not completely remove the smear layer from the root canal walls.

The key to successful endodontic treatment is shaping, cleaning, and sterilizing the root canal with hermetic filling without inflammation of the periapical area. Researchers are creating new techniques to facilitate clinical work and obtain a more efficient therapy. With the development of laser beams and accessories capable of delivering light into the root canal, it is possible to apply this new device in dentistry. In the next century, this technology will be used to clean and disinfect the radicular canal system [3–6].

Keller et al. [7] reported the use of Er:YAG laser, with a wavelength of 2.94 μm, that specifically removes enamel and dentin, which led to a series of studies leading to FDA approval of Er:YAG [8]. Takeda et al. [9] performed a comparative study of three kinds of laser, Nd:YAG, Argon, and Er:YAG, on the capacity of removing smear layer and concluded that the Er:YAG laser was the most effective for cleaning the root canal.

There are no reports in the literature on the interaction of laser with irrigating solutions for the preparation of root canals. Thus, we proposed to evaluate dentin permeability of the root canal walls after instrumentation associated with 1% NaOCl and distilled and deionized water, with and without Er:YAG laser application after instrumentation.

MATERIAL AND METHODS

The laser used in this study was Er:YAG (Kavo Key Laser II, Germany). Sodium hypochlorite (1%) and distilled and deionized water were obtained from the Endodontic Research Laboratory (FORP-USP, Ribeirão Preto, SP, Brazil). The NaOCl was also titrated.

A total of 25 extracted human maxillary incisors were distributed at random into five groups of five teeth each. Step-back instrumentation with K files (Maillefer, Switzerland) was performed. One minute instrumentation was standardized for each instrument. The canal was irrigated with 10 ml of irrigating solution with a final irrigation of 10 ml of distilled and deionized water. Group I: canal instrumentation and distilled and deionized water as the irrigating solution. Group II: canal instrumentation and 1% NaOCl as the irrigating solution. Group III: canal instrumentation and distilled and deionized water as the irrigating solution followed by Er:YAG laser irradiation. Group IV: canal instrumentation and 1% NaOCl as the irrigating solution followed by Er:YAG laser irradiation. Group V: canal instrumentation only up to #20 files with distilled and deionized water as the irrigating solution followed by Er:YAG laser instrumentation.

The Er:YAG laser was applied with the following parameters: 140 mJ, 15 Hz, 300 pulses, and 42 J. An E-2055 handpiece (Kavo), with the optic fiber corresponding to a #20–30 file, was used.

After preparation of the root canal as described above, the optic fiber was introduced until the apical region and the laser was activated. The optic fiber tip was gently removed from the root canal when 300 pulses, 42 J of energy, was achieved.

The teeth were immersed in 10% copper sulfate for 30 minutes, in a vacuum for the first 5 minutes. The teeth were then dried with paper points and placed in a 1% rubeanic acid alcohol solution for the same periods in solution and vacuum as above. Rubeanic acid reveals copper ions, forming a stained compound ranging in color from deep blue to black, depending on the quantity of copper ions present. Upon completion of this reaction, the tooth was placed in an acrylic resin block and 500-μm-thick transverse sections were obtained with a diamond disk from the cervical, middle, and apical thirds. During the sectioning process, constant irrigation with water was carried out to prevent dentin burn.

According to established criteria, each root third was cut into four slices and the second and fourth slices of each root third were used. The slices were then sanded under tap water to a thickness of approximately 100 μm and washed for 4 hours; they were dehydrated in a series of increasing alcohol solutions, cleared three times in xylol, and mounted on glass slides for microscopic examination.

The quantification of the penetration of copper ions was done by morphometry, with a 400-point grid. The number of points in the stained and nonstained areas of the dentin were counted. The percentage of copper ion penetration in the dentin (p(d)%) was calculated by the following equation: $p(d)\% = PM/(PT\text{-}PC) \times 100$, where PM = points in the stained area, PT = total number

TABLE 1. Percentage of Penetration of Cooper Ions in the Dentin of the Canal Walls*

Erbium	Erbium + NaOCl	Erbium + water	Water	1.0% NaOCl
7.80	13.30	14.90	4.50	13.30
10.00	12.30	18.10	6.30	17.70
8.20	13.20	12.90	7.93	11.37
9.20	11.40	14.20	5.49	12.38
9.20	8.40	13.50	6.11	12.15
9.80	11.90	17.10	4.50	13.25
11.10	16.10	17.40	4.61	19.77
9.40	16.90	14.40	4.65	8.62
9.90	8.40	14.70	3.92	14.25
8.90	8.40	13.70	4.50	10.95
10.10	5.40	10.50	2.50	5.24
10.50	10.60	10.30	0.95	8.78
5.10	10.80	8.20	1.82	6.45
7.30	1.50	10.10	2.09	9.25
7.90	6.70	10.30	0.00	8.66
$\overline{X} = 8.96 \pm 1.51^b$	$\overline{X} = 10.35 \pm 4.03^b$	$\overline{X} = 13.35 \pm 2.97^a$	$\overline{X} = 3.99 \pm 2.15^c$	$\overline{X} = 11.47 \pm 3.93^b$

*Different letters indicate statistical significance (Scheffé test, $P < 0.05$).

of points counted, and PC = points in the canal area [7].

RESULTS

The 75 data used in this study were the values corresponding to the penetration of cooper ions in the dentin of the canal walls (5 teeth × 5 treatments × 3 values per root = 75; Table 1). The test for normality showed that the distribution of the sample was normal, permitting the application of parametric analysis of variance, which indicated a statistically significant difference at the level of 1%. The Tukey test was applied to determine the difference between treatments. Analysis of multiple comparisons by using the Tukey test did not define the positioning of the component, sodium hypochlorite, as to its capacity to increase dentin permeability by using laser. This component was intermediate, grouping either with treatment with Er:YAG + water or with Er:YAG and Er:YAG + 1% NaOCl.

To determine the cleaning capacity of 1% sodium hypochlorite, the Scheffé test was used. This test classified the samples into three groups, in decreasing order when evaluating the increase in dentin permeability ($P < 0.05$): Group A, erbium + water; Group B, erbium, erbium + sodium hypochlorite and sodium hypochlorite; and Group C: water.

The figures show the Cu^{2+} ion penetration in the root canal dentine wall in cervical, middle, and apical thirds instrumented and irrigated with water and Er:YAG laser application (Fig. 1) or 1% sodium hypochlorite solution and Er:YAG laser application (Fig. 2).

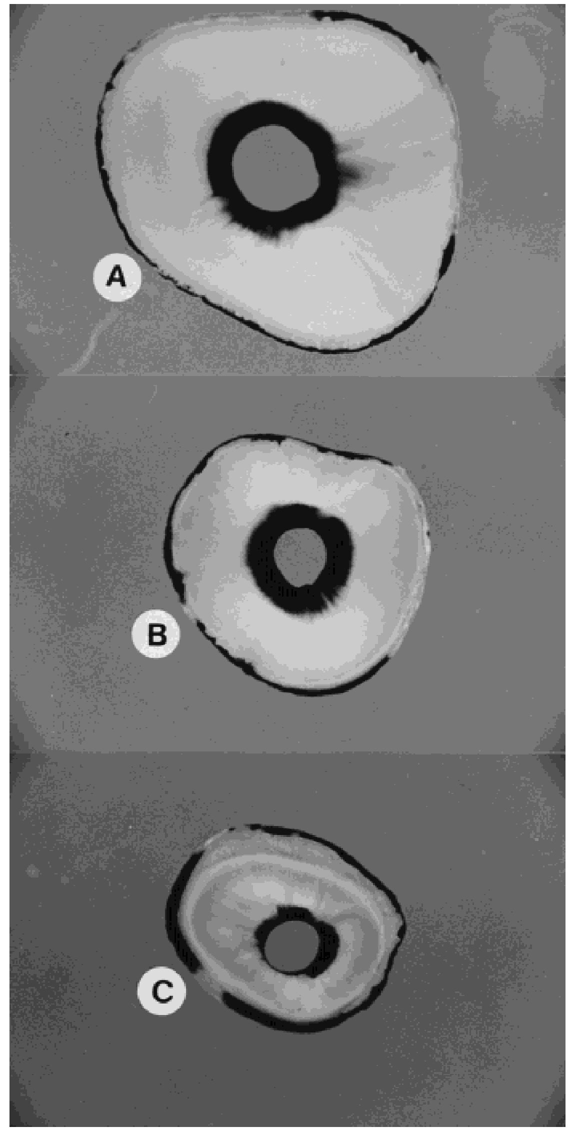

Fig. 1. Cu^{2+} ion penetration in the root canal dentine wall in cervical (**A**), middle (**B**), and (**C**) apical thirds instrumented and irrigated with distilled deionized water and Er:YAG laser application.

DISCUSSION

The root canals instrumented with water and irradiated with Er:YAG laser showed a greater increase in the radicular dentin permeability when compared with the other methods. The Er:YAG laser has affinity and interacts well with water, promoting greater dentin canaliculi

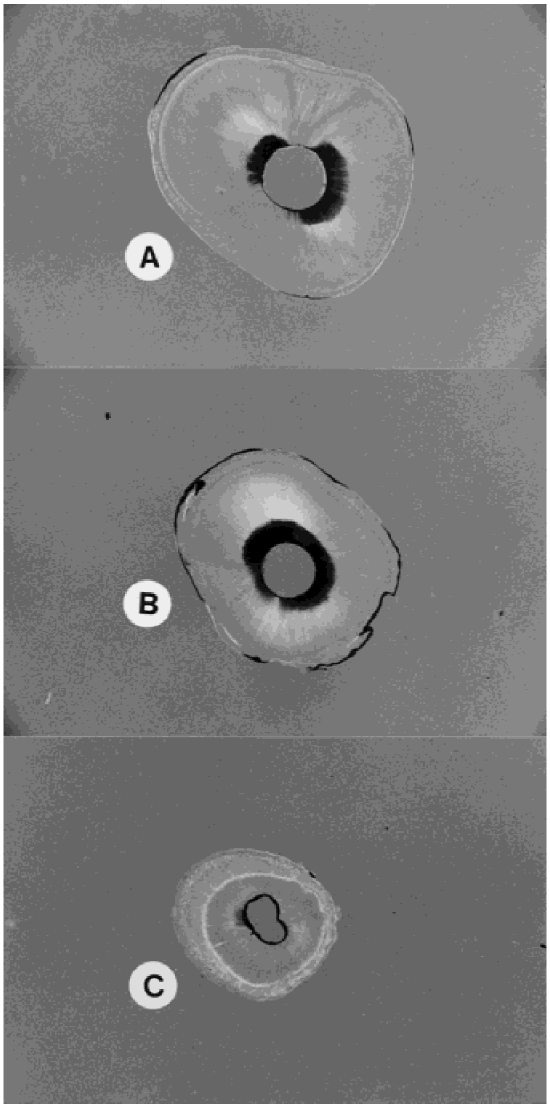

Fig. 2. Cu^{2+} ion penetration in the root canal dentine wall in cervical (**A**), middle (**B**), and (**C**) apical thirds instrumented and irrigated with 1.0% sodium hypochlorite solution and Er:YAG laser application.

opening. When only water was used as the irrigating solution, a small increase in dentin permeability was observed; however, its association with Er:YAG irradiation increased dentin permeability in a statistically significant manner.

Irrigation with water followed by laser irradiation increased dentin permeability in a statistically significant manner when compared with sodium hypochlorite irrigation either pure or irradiated with laser. Sodium hypochlorite did not interact as well as water with laser irradiation.

To explain the lower interaction of Er:YAG laser with 1.0% sodium hypochlorite, the ionic conductance of this substance was analyzed and compared with distilled and deionized water. The sodium hypochlorite solution showed values of 46.5 ms, whereas water was 1.0 ms. This difference means that the 1.0% sodium hypochlorite solution presents a larger quantity of free ions, which can be a decisive factor in the interaction with the Er:YAG laser.

Increasing root dentine permeability leads to higher cleanliness and more open tubules. This finding is an important factor for the disinfection of the root canals and a higher mechanical bonding between the root canal sealer and dentine.

The group instrumented until #20 file and then irradiated with Er:YAG laser increased the dentin permeability less than the group that used water + Er:YAG laser, because the water from the spray of the hand-piece does not totally fill the root canal.

This study is in accordance with the findings of Takeda et al. [4,5], which reported that Er:YAG laser was more effective in cleaning of the root canal, because it increases the permeability of dentine. This study points to new perspectives for research on the interactions of irrigating solutions with Er:YAG laser irradiation of root canals.

CONCLUSIONS

The instrumentation of the root canal that used water as the irrigating solution followed by Er:YAG laser irradiation promoted the greatest increase in dentin permeability. The use of Er:YAG laser, 1% sodium hypochlorite + Er:YAG, and 1% sodium hypochlorite used alone showed an intermediate capacity of increasing dentin permeability, in other words, greater than permeability produced by water and lower than water followed by Er:YAG laser. The use of water as the irrigating solution, without Er:YAG laser irradiation, promoted the least dentin permeability.

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